

EFFECTS OF IRRIGATION AND TIME OF APPLICATION ON THE YIELD AND QUALITY OF CV. CABERNET SAUVIGNON IN A WARM CLIMATE

LES EFFECTS DE L'IRRIGATION ET SON TEMPS D'APPLICATION SUR LE RENDEMENT ET LA QUALITÉ DU CABERNET SAUVIGNON DANS UN CLIMAT CHAUD

S. Sánchez-Élez¹; O. Fernández; L. Rodríguez; E. García; J.R. Lissarrague.

¹Sara Sánchez-Élez Martín, Group of Investigation in Viticulture, University Politechnic of Madrid (UPM), Senda del Rey s/n, 28040, Madrid, Spain. Telephone: 0034 914524900; e-mail: s.sanchez-elez@upm.es; gi.viticultura@upm.es

SUMMARY

Mediterranean climate is characterized by hot summer, high evapotranspiration rates, and scarce precipitations (400 mm per year) during grapevine cycle. These extremely dry conditions affect vineyard productivity and sustainability. Supplementary irrigation is a needed practice in order to maintain yield and quality.

Almost all Spanish grape growing regions are characterized by these within this context, especially in the center region, where this study was performed. The main objective of this work was to study the influence of irrigation on yield and quality. For this aim, we applied different levels of irrigation (mm of water applied) during different stages of growth and berry maturity. Four experimental treatments were applied considering the amount of water and the moment of the application:

- T1: Water irrigation (420 mm) applied from bloom to maturity.
- T2: Corresponded to the traditional irrigation scheduling, from pre-veraison to maturity (154 mm).
- T3: Water irrigation from bloom to pre-veraison, and water deficit from veraison to maturity (312 mm).
- T4: Irrigation applied from pre-veraison to maturity (230 mm)

Experimental vineyard, cv. Cabernet Sauvignon, was located in a commercial vineyard (Bodegas Licinia S.L.) in the hot region of Morata de Tajuña (Madrid). The trial was performed during 2010 and 2011 seasons.

Our results showed that yield increased from 2010 to 2011 in the treatments with a higher amount of water applied, T1 and T3 (24 and 10 % of yield increase respectively). This was mainly due to an increase in bud fertility (n° of bunches per shoot). Furthermore, sugar content was higher in T3 (27.3 °Brix), followed by T2 (27 °Brix). By contrast, T4 (irrigation from veraison) presented the lowest solid soluble concentration and the highest acidity.

These results suggest that grapevine has an intrinsic capacity to adapt to its environment. However, this adaptation capacity should be evaluated considering the sensibility of quality parameters during the maturity period (acidity, pH, aroma, color...) and its impact on yield. Here, we demonstrated that a higher amount of water irrigation applied was no linked to a negative effect on quality.

RÉSUMÉ

Les zones méditerranéennes sont caractérisées par des conditions climatiques chaudes et humides, des taux élevés d'évapotranspiration, et par des précipitations peu abondantes (400 mm par année) pendant le cycle végétatif de la vigne. Ces conditions extrêmement sèches affectent la productivité et la durabilité des vignobles. L'irrigation supplémentaire est donc, une pratique nécessaire pour maintenir le rendement et la qualité.

En Espagne, la plupart des régions viticoles présentent ce type de climat, avec des étés secs et chauds, en particulier dans la région centre, où cette étude a été réalisée. L'objectif principal de ce travail a été d'étudier l'influence de l'irrigation sur le rendement et la qualité. Pour ce faire, quatre niveaux d'irrigation différents (mm d'eau appliquée) ont été appliqués au cours des différentes étapes de la croissance et de la maturité des baies.

- T1: irrigation (420 mm) appliquée à partir de la floraison à la maturité.
- T2: irrigation traditionnelle, à partir de pré-véraison à maturité (154 mm).
- T3: irrigation à partir de la floraison jusqu'au pré-véraison (312 mm), avec une contrainte hydrique depuis veraison à maturité.
- T4: Irrigation appliquée depuis pré-véraison à maturité (230 mm)

Le vignoble expérimental de la cv. Cabernet Sauvignon, était situé dans un domaine commercial (Bodegas Licinia SL) dans la région de Morata de Tajuña (Madrid). L'essai a été réalisé en 2010 et 2011.

Nos résultats ont montré que le rendement a augmenté de 2010 à 2011 dans les traitements avec une plus grande quantité d'eau appliquée, T1 et T3 (24 et 10% d'augmentation du rendement respectivement). Cela était principalement dû à une augmentation de la fertilité (n° de grappes par rameau). D'ailleurs, la teneur en sucre était plus élevée dans T3 (27,3° Brix), suivie de T2 (27° Brix). En revanche, T4 (irrigation à partir de la véraison) a présenté la plus faible concentration de sucres solubles et une acidité plus élevée.

Ces résultats suggèrent que la vigne possède une capacité intrinsèque pour s'adapter à son environnement. Cependant, cette capacité d'adaptation devrait être évaluée compte tenu de la sensibilité des paramètres de la qualité au cours de la période de maturité (acidité, pH,

arôme, couleur ...etc.) et leur impact sur le rendement. Nous avons démontré ici qu'une plus grande quantité d'irrigation appliquée n'a pas affecté de façon négative la qualité.

Keywords: Irrigation, berry, Cabernet sauvignon.

Mots-clés: Irrigation, raisin, Cabernet sauvignon.

INTRODUCTION

In Mediterranean climate regions, with hot summers, high evapotranspiration rates, low relative humidity as well as intermittent and scarce rainfall (400 mm per year) which reduce winter water recharge soil profile, the productivity and sustainability of the crop is affected. So supplemental irrigation becomes necessary to achieve an adequate vintage and of a high quality (see Table I).

This work aims to study deficit irrigation strategies applied at different times of growth and grape development, from flowering to leaf fall, and to see how it affects the yield of the vine and the grape quality.

MATERIALS AND METHODS

The trial was conducted in 2010 and 2011 in a commercial vineyard, Bodegas Licinia S.L., located

TABLE I

Evolution of climatic characteristics in the center of the Iberian peninsula. Meteorological Characteristics of Madrid. Weather Station Four Winds (Middle Year: 1971-2000). Source: www.aemet.es. Meteorological characteristics of the two-year trial with Cabernet Sauvignon (Climatic Station in the plot).

Evolution des caractéristiques climatiques dans le centre de la péninsule ibérique. Caractéristiques météorologiques de Madrid. Station météo Quatre Vents (Moyen Année: 1971-2000). Source: www.aemet.es. Caractéristiques météorologiques de l'essai de deux ans avec le Cabernet Sauvignon (Station climatique de la parcelle).

Annual	Tm (°C)	Tmax (°C)	Tmin (°C)	% HR	P (mm)	Eto (mm/día)
1971-2000	14	20	8.7	59	449	3.40
2010-2011	14.36	21.07	7.97	65	405.1	4.89

Most of the wine grape vineyards are located in such Mediterranean areas, where the periods of development and maturation are dry, hot with a great light stress, and where the water, thermal and hygrometric stresses are frequent. Controlled deficit irrigation applications are managed in many cropping strategies. Less water than the one that potentially the plant transpires is supplied to achieve an increase in yield (due to a reduction in the vegetative development that also reduces green interventions) and better qualitative characteristics of the must.

Water availability throughout the growing season has a decisive influence in the vine photosynthetic capacity and in plant response to variations in the environmental conditions. It is a decisive factor for root development, and this is of great importance in crop growth, in the vegetative and reproductive development, and in its potential yield.

Generally in Mediterranean areas, the constraints to development begin in flowering, when soil water contents do not satisfy peak demand conditions and the leaf area achieved. Plants show resistance mechanisms to drought by morphological and physiological processes, i.e. main branch elongation and leaf growth decrease which impact on total surface area.

at Morata de Tajuña, Madrid (40° 12' N; 3° 28' W; 550 m above sea level), located in the middle of the Iberian peninsula. Cabernet Sauvignon clone 15, rootstock 41B, was planted in 2005 in oriented rows north-to-south with a vine by row spacing of 3 by 1 m. Vines were pruned to two spur, in a 10-node fruiting arm, according to ecological practice.

The climate is Mediterranean continental with 400 mm of annual rainfall, most of it concentrated during spring and autumn seasons. Therefore this climate has cold winters and hot summers. Climatic parameters during the trial were measured each day with an automatic weather station located in the plot. Reference evapotranspiration (ET_0) was calculated using the modified method of Penman-Monteith (FAO, 1990).

Budbreak for *Vitis vinifera* in this location occurs around the middle of April; veraison, at the beginning of August; and harvest, and around the end of September.

Experimental design: a randomized complete block design with three replications was used. Each plot had 90 control vines (30 vines x 3 rows). Vines were drip-irrigated with 2.5 l/h emitters spaced every 1 m.

The study in 2010 and 2011 consisted of applied different rates of irrigation (mm of water applied) during different stages of growth and berry

maturation. Four experimental treatments were applied considering the amount of water and the moment of the application: Water irrigation (0.6 ET₀) applied from bloom to maturity (T1); Corresponded to the traditional irrigation scheduling (T2), from pre-veraison to maturity (0.3 ET₀); (T3) Water irrigation from bloom to pre-veraison (0.45 ET₀), and water deficit from veraison to maturity (0.2-0.3 ET₀); irrigation applied from pre-veraison to maturity (T4) (0.6 ET₀). (see, figure 1.)

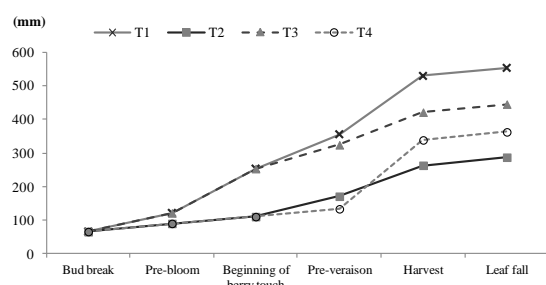


Figure 1- Effective precipitation + irrigation water applied (mm) to 4 treatments. Mean 2010-2011. Budbreak - leaf fall.

La précipitation efficace + eau d'irrigation (mm) à 4 traitements. Moyenne 2010-2011. Pousse - chute des feuilles.

Data analysis. Analysis of variance (ANOVA) was performed using SPSS statistical software (version 15.0; SPSS Inc., Chicago, IL). Probability of significant difference among treatment levels ($p \leq 0.05$) was determined using the Duncan's Test.

Day of year (DOY) for budbreak, bloom and veraison was determined by visual inspection when 50% of buds or clusters reached stages 4, 23 and 35 of the modified Eichhorn-Lorenz system (Coombe 1995). Leaf Area Index (LAI) measured at veraison according to Sánchez de Miguel *et al.* (2011) from 2 shoots per vine and 10 vine per plot. From veraison a 100 berry sample per plot was collected to follow the ripening process by measuring berries weight (g), SST (°Brix), pH and Titratable acidity to pH = 8.2 endpoint. Yield per vine was calculated at harvest by weighting the clusters harvested from each of the 20 vines per plot.

RESULTS AND DISCUSSION

Irrigation rates influences vineyard productivity, in the leaf development and biomass production, so as in the number and weight of the berry. Moreover, it also depends on the phenological stage of the vineyard.

Different parameters and indices have been used, such as LAI (Leaf Area Index) which indicates the

total surface area developed by the whole vineyard and by the vine. This is a decisive factor in overall productivity, especially in the photoassimilates production, which increase with the development of the leaf area to a point beyond which increasing the vegetation density limits the number of leaves exposed to direct radiation (Reynier, 2000). LAI/SA relation (Smart *et al.* 1985), represents the mean leaf surface which benefits from full exposure to sunlight. The most irrigated treatments (T1 and T3) are those that develop greater surface area, besides having a good exposition of leaves ($LAI/SA_{T1} = 1.49$; $LAI/SA_{T3} = 1.57$). Smart and Robinson recommend 1 to 1.5 as optimum values.

Furthermore, dry matter production is the indicator of the production of a vineyard (Carbonneau y Casteran, 1986). Yuste (1995) argues that biomass analysis of renewable plant organs, expressed as dry matter, is an objective form to evaluate the growth and development and to quantify the productive potential of the vine in certain conditions. Water availability generally increases dry matter production; in this case with higher irrigation rates the overall productivity was increased.

To estimate the balance between vine vegetative growth and yield Ravaz index has been used, being the optimum range for the index from 4 to 7 (Smart *et al.*, 1991; Murisier 1996 en Rubio 2002). With the mean shoot weight, the difference in wood maturation due to water availability and year can be sensed-intuited. Balanced vines show shoots with a an average weight for 30–40 g per shoot, preferably of 40 g in hot climates (Baeza y Lissarrague, 2001). Water availability affects the weight per shoot, being higher in the treatments that received water intake in the vegetative stage (T1 and T3). (see table II)

The final berry weight is a production determining factor; this weight depends on the metabolic processes of the berry and the vine, i.e. anything that affects the cell division process in the berry or the photosynthetic capacity in plant, will affect the berry weight and therefore the yield. Water is the major component of grapes, and the amount of it determined the volume of them. There are not significant differences in 2010 yield, but there are in 2011. In both years grape yield was greater in those treatments with the higher water application, treatment 1 and 3 (24 y 10% respectively), due to increasing vine shoot fertility (see table III).

Moreover the sugar content is higher in Treatment 3 (large water supply from flowering and the reduction of the intake in pre-veraison: 27.3 °Brix). It was followed by Treatment 2 (conventional irrigation: 27 °Brix). However Treatment 4 (water

TABLE II

Vegetative development (LAI, m²/m², and LAI/SA), Ravaz's index (Yield/pruning weight); production of biomass (MST; kg/m²); shoot weight (g); in 2010 and 2011 for Cabernet Sauvignon under 4 water regimes (T1, T2, T3, T4).

Développement végétatif (LAI, m²/m² et LAI / SA), l'indice de Ravaz (Rendement / élagage poids), la production de biomasse (MST; kg/m²); poids des pousses (g), en 2010 et 2011 pour le Cabernet Sauvignon.

	LAI (m ² /m ²)		LAI/SA		LAI/Yield (m ² /kg)		I Ravaz		MS T (Kg/m ²)		Shoot weight (g)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T1	1.49 a	1.32 a	1.65	1.62	1.97	1.37	3.26 b	4.40	0.55 ab	0.61 a	68.36 a	67.80 a
T2	0.89 b	0.97 c	1.20	1.32	1.34	1.44	4.57 a	5.17	0.47 b	0.44 b	44.30 b	40.89 d
T3	1.57 a	1.22 ab	1.72	1.57	2.11	1.47	3.30 b	4.40	0.57 a	0.58 a	67.61 a	58.92 b
T4	1.01 b	1.06 bc	1.31	1.44	1.49	1.50	4.02 ab	4.51	0.47 b	0.44 b	51.12 b	47.96 c
Sig.	**	*	ns	ns	ns	ns	**	ns	*	***	**	***

TABLE III

Yield component in 2010 – 2011 growing seasons for Cabernet Sauvignon under 4 water regimes.

Composante du rendement en 2010 - 2011 saisons de croissance pour Cabernet Sauvignon.

	Yield (kg/ha)		Cluster weight (g)		Berry weight (g)		Berries/cluster		Cluster/shoot	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T1	7726.67	9619.17 a	131.84 a	129.43 a	1.09 a	1.02 a	120.76	128.69	1.69	2.24 a
T2	6705.56	6721.11 b	107.99 b	97.67 b	0.96 b	0.82 b	112.52	118.45	1.86	2.05 b
T3	7576.67	8252.12 ab	131.36 a	117.18 ab	0.99 ab	0.89 b	132.80	131.72	1.71	2.11 ab
T4	6837.78	7051.11 b	115.97 ab	101.38 b	0.89 b	0.81 b	130.81	124.68	1.77	2.07 b
Sig.	ns	***	**	***	**	***	ns	ns	ns	*

supply from pre-veraison) is the treatment with the lowest concentration of soluble solids, but the one with the higher acidity (see table IV).

CONCLUSIONS

The watering regime influences the productivity of the vineyard and grape quality. The moment of irrigation application also influences, developing a greater vegetative growth in treatments where irrigation begins at late flowering – fruit set (T1 and T3), as an increasing biomass production, and the

weight per shoot of the vine, ensuring the crop sustainability. These treatments also affect the grape quality; one of the major problems in hot climates with low rainfall during the summer season is the high concentration of sugars and the low acidity of the grapes. Changing the irrigation doses and the moment of its application throughout the development and maturation of the berry, such problems can be enhanced as seen with Treatment 4 (water supply from pre-veraison), in which the concentration of soluble solids decreases compared to other treatments, but it also has a higher acidity.

TABLE IV

Must composition at harvest in 2010 and 2011 for Cabernet Sauvignon under four irrigation regimes (T1, T2, T3, T4).

Composition à la récolte en 2010 et 2011 pour le cabernet sauvignon sous quatre régimes d'irrigation (T1, T2, T3, T4).

	100 berries weight (g)		SST (°Brix)		Titratable acidity (g TH/L)		pH		grams of sugar in 100 berries (g)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T1	109.17 a	102.1 a	26.10	27.6 b	5.17	4.88 c	3.50	3.46 b	18.25 a	17.97 a
T2	95.52 bc	82.4 b	26.70	28.3 ab	4.78	5.25 b	3.45	3.41 ab	16.30 b	14.86 b
T3	99.11 b	88.8 b	26.07	29.0 a	4.80	5.50 b	3.55	3.43 a	16.55 b	16.38 b
T4	88.66 c	81.4 b	25.60	25.3 c	4.84	5.81 a	3.42	3.23 c	14.56 c	13.24 c
Sig.	**	***	ns	***	ns	***	ns	**	**	***

Sig.: signification for *, **, ***, ns is significant for $p < 0.05$, $p < 0.01$, $p < 0.001$, and no significant respectively. Mean separation by Duncan's Test for $p = 0.05$.

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